920

INCLINOMETERS
FOR
AERIAL NAVIGATION

PREPARED IN THE OFFICE OF
THE DIRECTOR OF AIR SERVICE

July, 1919

WASHINGTON
GOVERNMENT PRINTING OFFICE
1919

War Department
Document No. 920
Office of The Adjutant General

WAR DEPARTMENT,
WASHINGTON, *July 31, 1919.*

The following publication, entitled "Inclinometers for Aerial Navigation," is published for the information and guidance of all concerned.

[062.11, A. G. O.]

BY ORDER OF THE SECRETARY OF WAR:

PEYTON C. MARCH,
General, Chief of Staff.

OFFICIAL:

P. C. HARRIS,
The Adjutant General.

131703—19

INCLINOMETERS.

1. Use.

The purpose of an inclinometer is to show the lateral or longitudinal inclination of an airplane to the horizontal. In order to be effective at all times such an instrument should be stabilized, either by a gyrostat or some other means, so that there is always either a vertical line or horizontal plane for reference. Since the problem of stabilization is a difficult one and requires complicated and expensive mechanism, *stabilized* inclinometers have only been used for special purposes and tests.

The bubble, or "spirit level," inclinometers that have been adopted are subject to all the accelerations of the airplane, including the centrifugal force involved on turns. Consequently they give *reliable* information on the position of the airplane *only when flying in a straight line with uniform speed.* A misunderstanding of this often leads to a failure to get any use of the instrument.

On a properly banked turn the airplane, or any object in it, is subjected to a force which is the resultant of the force of gravity and the centrifugal force and is normal to the lateral, or athwartship axis of the airplane, just the same as is the force of gravity when flying level. This resultant force is sometimes called "false gravity." Consequently a lateral bubble inclinometer will read zero on a *properly* banked turn, and if it does not read zero the bank should be changed until it does. However, the side wind on the pilot's face is a more sensitive detector of a side-slip or skid, so such an instrument is not important on an open airplane. In a skid the bubble moves in the opposite direction to the skid. For example, if in turning to the left the bubble moves to the left of zero the ship is skidding; but if the bubble moves to the right the ship is side-slipping. The inclinometer may be used to give the angle of inclination in a deliberate side-slip, but only after the airplane has settled down to a steady motion; for on entering a side-slip there is a turning which results in a centrifugal force which affects the motion of the bubble.

The longitudinal inclinometer will give the angle the longitudinal axis of the airplane makes with the horizontal provided the machine is climbing or gliding uniformly. On a "zoom" or dive the acceleration will have a large effect on the bubble position.

Banking indicators and inclinometers of the pendulum type (for example, the Sperry instruments) are subject to the same errors as

the bubble inclinometers, and are not as sensitive. Since the latter are simpler and lighter, they are to be preferred. (One should be cautioned not to confuse the purpose of a banking indicator with a *turn indicator*, which is described in another pamphlet.)

2. Construction.

The inclinometer shown in the figure may be used either as a lateral or longitudinal instrument. The tube is set in a bed of plaster of Paris in the frame in such a manner that it is well protected, and there is little danger of breaking. Special devices are used to make the bubble visible in the dark. The liquid, which is mainly alcohol, contains 10 per cent fluorescein; along the back of the tube there is a strip of luminous paint, and the markings of the scale coated with luminous paint.

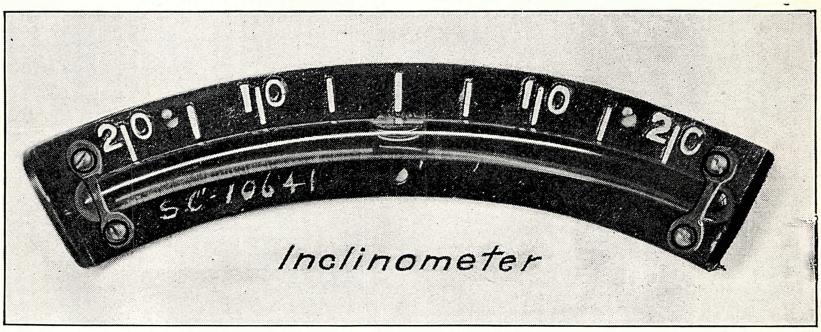
3. Installation.

The lateral inclinometer is mounted on the instrument board. It should be so placed that the reading is zero when the lateral axis is horizontal. This can be tested by using a spirit level to see that the floor of the fusilage or the lower edge of the instrument board is level. The longitudinal inclinometer may be mounted any place along the side of the fusilage, where it may be read conveniently. But as with the lateral inclinometer, it should be so mounted that the bubble is zero when the longitudinal axis is horizontal. In some ships, but *not all*, the top longeron is parallel to the longitudinal axis, and the inclinometer may be mounted with this for reference. Otherwise the airplane must be leveled up before the inclinometer is fastened in place.

References.

B. A. P. Specifications No. 27065.
P. E. D. Drawing No. 030037.
Aeronautical Instruments Circular No. 27, Bureau of Standards.

○



Inclinometer